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DFA Propane Mixer Evaluation

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DFA Propane Mixer Evaluation

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Abstract: A detailed test of the Dual Fuels Associates (Orem, Utah, USA) propane mixer was conducted at the MTC Downsview chassis dynamometer facility. The unique-design propane mixer was evaluated for air/fuel ratio control, exhaust emissions, and fuel consumption and was compared to a previous propane conversion on the the same test vehicle. The results indicate that the mixer is capable of metering propane with reasonable precision without offering a significant restriction to engine intake airflow.			
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PREFACE

The Ontario government industrial development agency, IDEA Corporation, approached the Ministry of Transportation and Communications (MTC) for assistance in evaluating a potential industrial development candidate. Specifically, it was necessary to determine the validity of the manufacturer's claims regarding his new concept gaseous fuel mixer. This mixer is part of a propane conversion kit that the candidate intends to manufacture in Ontario.

ACKNOWLEDGEMENTS

The assistance of the MTC chassis dynamometer staff, Mr. Norm Perfect, and Mr. Eric Rieder is gratefully acknowledged.

EXECUTIVE SUMMARY

This test program with the Dual Fuels Associates (DFA) Corporation dual-fuel propane mixer unit was intended to evaluate the manufacturer's claims regarding performance, fuel consumption, exhaust emissions, and air/fuel ratio control.

The program involved chassis dynamometer testing of a 1981 Ford F150 pickup truck, first using gasoline, then gasoline with the dual-fuel mixer in place, and then propane. A subjective evaluation of drivability was also done.

The manufacturer's claims are as follows:

- mixes air/fuel completely, giving equivalent power to gasoline;
- maintains stoichiometric (chemically ideal) operation from idle to full throttle;
- no air restriction on gasoline;
- fits within existing air cleaner;
- retains all original equipment manufacturer (OEM) equipment;
- no moving parts/no maintenance.

In the tests on this particular vehicle, the mixer performance met most of the manufacturer's claims. Since the test results are based on a one-vehicle evaluation, however, no attempt is made to generalize the results to other vehicles or manufacturers.

Wide-open-throttle (WOT) gasoline performance was slightly degraded by the presence of the mixer. Performance on propane was reduced further. This is typical of most propane conversions.

After proper adjustments were made, the mixer was able to control the mixture with reasonable precision under all off-idle/part-load conditions. No significant transient drivability problems, such as engine hesitations, were experienced.

Exhaust emissions were similar to those of gasoline, except for a substantial reduction in carbon monoxide (CO) level. The mixer slightly leaned the gasoline mixture, which reduced the CO emissions. A minimal fuel economy benefit was also noted. The advance of the ignition timing by 2° in the Dual Fuels Associates (DFA) conversion may have been a contributing factor.

The only major installation problem involved the vehicle air cleaner. The supplied DFA mixer had not been designed to fit the Ford offset air cleaner, necessitating the purchase of a standard air cleaner (\$200 Canadian). The air cleaner tray was modified to accept the factory emission control devices, and the mixer was installed. It is suggested that DFA design a mixer to alleviate this problem.

The vehicle manufacturers have recently introduced electronic engine controls (EEC) to their product lines. This trend is expected to result in total EEC use by about 1988. The alternative fuel conversion industry must respond to this situation by ensuring that their equipment is compatible with the original equipment manufacturers' EEC systems. Although DFA claim that their equipment can be used on EEC-equipped vehicles, this claim could not be evaluated in the MTC test program because of time limitations.

1/ INTRODUCTION

A dual-fuel propane conversion kit suitable for use on a Ford 4.9 L (300 in³ displacement [CID]) in-line six-cylinder engine was supplied to the Ministry of Transportation and Communications (MTC) by the manufacturer, Dual Fuels Associates (DFA) Corporation of Orem, Utah, USA. This kit consists of a Beam converter/regulator assembly, air cleaner mixer unit, adjustable fuel vapour elbow, gasoline and propane fuel locks, fuel vapour line, wiring, and switches.

These components were installed on a 1981 Ford F150 4.9 L (300 CID) automatic transmission pickup truck (Appendix A). This vehicle had previously been used for evaluation of other propane conversion kits. It was returned to factory stock condition by installing a new carburetor and distributor assembly and ensuring that all emission components were connected and operating. The vehicle was then set up according to the manufacturer's specifications (initial ignition timing, idle speeds, and idle mixture).

Before the conversion to propane, it was found that the mixer unit would not fit inside the Ford original equipment offset air cleaner. It was necessary to purchase, and slightly modify, a standard Ford air cleaner at a cost of approximately \$200 (Canadian) to allow installation of the small mixer unit. It should be noted that the offset air cleaner is the only one that will fit a six-cylinder Ford van, and thus, DFA should consider designing a mixer unit for this style of air cleaner. The objective of this testing was to determine the technical validity of the manufacturer's claims regarding the product.

1.1/ Manufacturer's Claims

- 1/ Mixes air/fuel completely, giving equivalent power to gasoline.
- 2/ Maintains stoichiometric (ideal) operation from idle to full throttle.
- 3/ No air restriction on gasoline.
- 4/ Fits within existing air cleaner.
- 5/ Retains all original equipment manufacturer (OEM) equipment.
- 6/ No moving parts/no maintenance.

1.2/ The Future of Gaseous Fuel Conversions

A relatively recent development in the vehicle manufacturing sector is the introduction of electronic engine controls (EEC) to gasoline vehicles. It is expected that within the 1985-1988 time period, the North American manufacturers will produce nothing but EEC-equipped vehicles. The alternative fuel conversion industry must respond to this situation

by developing conversions which are compatible with the original equipment manufacturers' EEC systems. This is especially critical on dual-fuel conversions, where operation on gasoline must not be affected by the installation of external devices. Although DFA claims that their equipment can be used on EEC-equipped vehicles, this claim could not be evaluated in the MTC test program because of time limitations.

2/ THE TEST PROGRAM

All tests were performed at the MTC chassis dynamometer facility (Appendix B) in Downsview.

2.1/ Test Procedures

The test procedures were intended to assess vehicle performance, fuel consumption, and exhaust emissions on gasoline and propane motor fuel (see Appendix C for fuel specifications). The latter two were evaluated via the Environmental Protection Agency (EPA)/Transport Canada constant volume sampling (CVS) test procedure (Appendix D). Performance testing was limited to acceleration times (0 to 96.5 km/h [0 to 60 mph]) at wide open throttle (WOT) in drive gear (i.e., first, then second, as the second to third upshift did not occur before 96.5 km/h [60 mph]) and second gear. Intake manifold vacuum data were recorded from a dial gauge connected to an intake runner port.

Also performed were air/fuel (A/F) equivalence ratio traces to determine steady-state air/fuel mixtures at idle and several road speeds up to 96.5 km/h (60 mph). All data were taken from tail pipe samples, downstream of the catalytic converter, with the exhaust air pump disconnected (per Beckman air/fuel ratio meter instructions).

Four vehicle conditions were tested:

- 1/ operation with regular unleaded gasoline without the DFA mixer installed;
- 2/ operation with gasoline with the mixer installed;
- 3/ operation with propane, installed per DFA instructions (before mixture adjustment);
- 4/ operation with propane, after mixture adjustment to reduce fuel consumption.

2.2/ Error Assessment

An attempt to quantify the experimental errors was made to assist in data comparison. All CVS test data (fuel consumption and emissions) were considered to be within (+/-) 3% of the actual values. This is based on the test equipment manufacturers' claims and MTC's six years of experience with the dynamometer facility (Appendix E).

Performance tests were done on the dynamometer rolls, using a stopwatch. These acceleration times (0 to 96.5 km/h [0 to 60 mph]) are believed to be within a 0.5 s measurement error range. It should be noted that the dynamometer test cell is not a precisely controlled environment area (although temperature control has been demonstrated within a 4°C range).

While the CVS tests are corrected for ambient variability, the acceleration times are not. Overall, day-to-day vehicle performance variability of up to 1.0 s range was evident. The resultant total error range estimate was 1.5 s. (To be conservative, the total error range estimates were obtained by summing the absolute measurement error range and the observed maximum day-to-day variability. This provides a reasonable level of confidence in the data, allowing comparisons and general conclusions to be drawn.) The manifold vacuum readings were estimated to be accurate within a 0.5 in. Hg range.

Air/fuel equivalence ratio measurements are claimed by the analyser manufacturer to be within 0.1 air/fuel ratio of the correct value. This gives an absolute measurement error range of about 0.014 equivalence ratio near stoichiometry. Again, vehicle environmental conditions and day-to-day variability resulted in up to 0.07 equivalence ratio change.

Spark advance data was estimated to be within a 1.5 distributor degree total error range (3.0 crankshaft degrees). It was not possible to investigate ignition system variability within the time and budget constraints of this test.

Where possible, average values are used in the figures to simplify their appearance. The magnitude of the day-to-day vehicle variability illustrates the difficulty involved in making precise comparisons between results obtained from vehicle testing under changing conditions.

3/ RESULTS AND DISCUSSION

The conversion instructions required that the initial ignition timing be advanced by 2 to 12° before top dead centre (BTDC). The baseline gasoline tests without the mixer in place were done at the stock 10° BTDC setting. This factor, while minor in nature, should be kept in mind when comparisons with the baseline gasoline tests are made.

3.1/ Performance

No significant loss of performance was noted when the mixer was in place and the vehicle was running with gasoline. A WOT average acceleration time (0 to 96.5 km/h [0 to 60 mph]) increase of 1.7 s was experienced when operating using propane prior to mixture adjustment. After the mixture was leaned out, the average increase fell to the 0.7 s level (Figures 1 and 3).

During exclusive second gear operation, an average 0.6 s increase was noted with the mixer in place using gasoline. The average loss on propane was about 2.2 s before adjustment and 0.8 s after adjustment (Figures 2 and 3).

The larger performance loss before the propane mixture was adjusted illustrates the effect of incorrect fuel mixtures on engine power output (i.e., too rich). WOT manifold vacuum readings were consistently in the 1.0 to 1.5 in. Hg range (Appendix F). The baseline gasoline test values were in the 1.0 in. Hg range. This is additional evidence of the lack of significant intake air restriction offered by the DFA mixer unit.

3.2/ Fuel Consumption

A 20% increase in volumetric fuel consumption was experienced when operating on the urban test cycle after mixture adjustment (the average typical conversion increase is about 22%). Propane has about 27% less energy per litre than gasoline, and an average 11% reduction in urban cycle energy consumption was experienced (Appendix G). A 25% increase (typical value) in highway cycle volumetric fuel consumption was offset by the energy content difference, giving an average 7% energy consumption reduction (Figures 4 and 5). Before mixture adjustment, comparable urban energy consumption was evident, along with an 8% increase in the highway cycle. This demonstrates the need for proper propane mixture adjustment when performing a conversion. In this case the adjustment resulted in an average 11% improvement in the urban cycle and a 14% improvement in average highway cycle energy consumption. The previously tested conversion, which employed a dedicated propane mixer, showed a 5% energy consumption increase in both the urban and highway cycles when compared to the

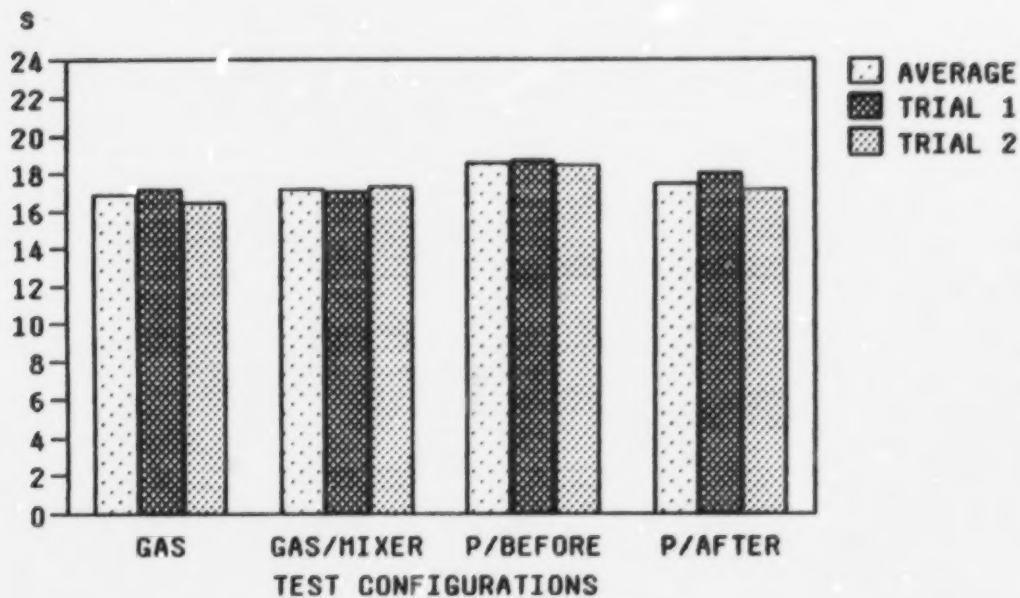


Figure 1/ WOT Acceleration of 0-96.6 km/h (0-60 mph),
Uncorrected, Drive Gear

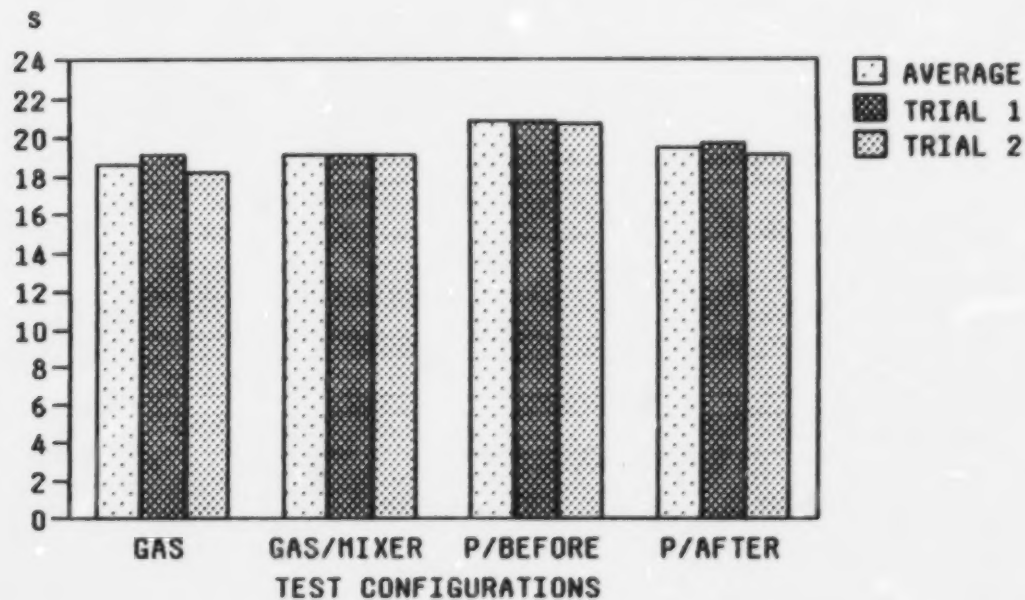


Figure 2/ WOT Acceleration of 0-96.6 km/h (0-60 mph),
Uncorrected, Second Gear

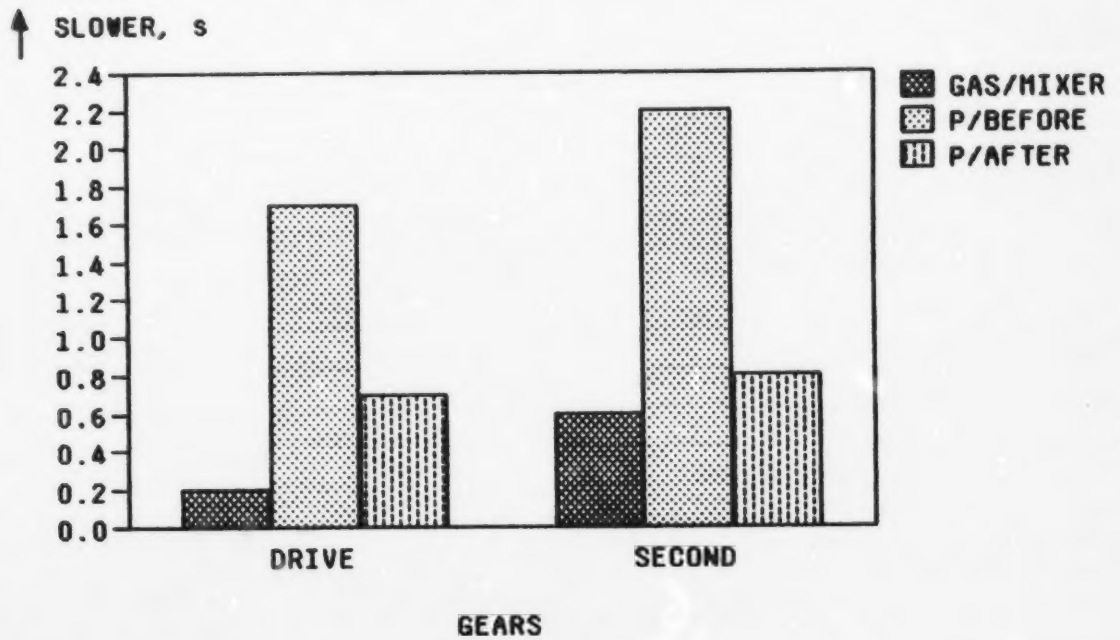


Figure 3/ Average WOT Performance Loss —
0-96.6 km/h (0-60 mph), Uncorrected, vs. Gasoline

L/100 km

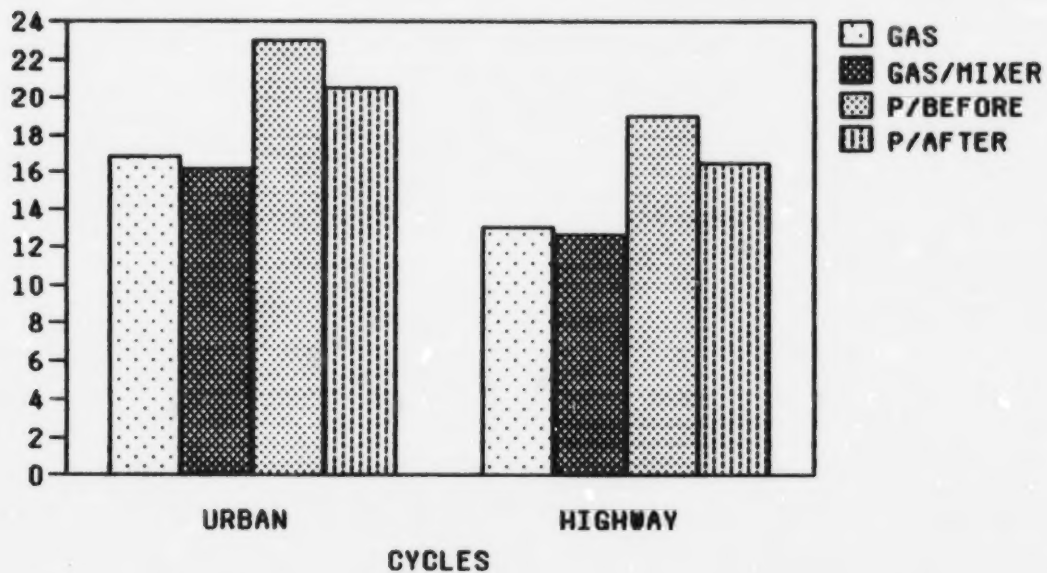


Figure 4/ CVS Fuel Consumption —
Volumetric, Urban/Highway Cycles

MJ/100 km

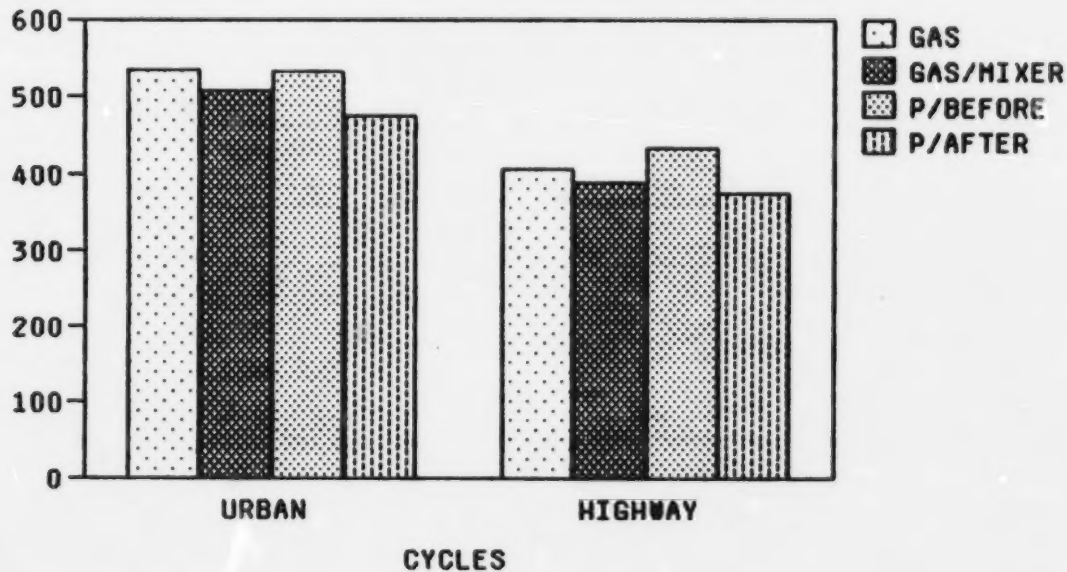


Figure 5/ CVS Energy Consumption —
Urban/Highway Cycles

previous baseline gasoline results (Section 3.7 and Appendix G). For fuel consumption data, see Appendix H.

3.3/ Exhaust Emissions

Hydrocarbon emissions increased slightly when operating with propane. Carbon monoxide emissions were reduced substantially once the system had been adjusted. Nitrous oxides (NO_x) increased very slightly (Figure 6 and Appendix I). The emission results are primarily a function of air/fuel ratio, and it is possible to make small adjustments to the mixture which produce large relative changes in CO emission levels. These three pollutants are collectively close to their lowest levels when the mixture is near stoichiometric (equivalence ratio = 1.0). However, this is the point where maximum exhaust temperatures occur, and it is desirable to run slightly rich or lean compared with this point to maintain valve and valve seat durability.

3.4/ Air/Fuel Equivalence Ratios

Air/fuel ratio data showed that the DFA propane conversion was not providing stoichiometric operation under part-load conditions. Fuel consumption values were higher than expected. It was necessary to adjust the fuel vapour elbow to restrict the flow of fuel at higher engine speeds/loads and reset the idle mixture via the converter/regulator idle pressure setting (Figures 7 and 8 and Appendix J).

Once the adjustment was made, fuel consumption dropped by 11% (urban) and 14% (highway). Most exhaust emissions were reduced (by about 10 g/mi for carbon monoxide and 0.1 g/mi for hydrocarbons), except for nitrous oxides, which increased by 0.9 g/mi. Stoichiometry was essentially maintained under all off-idle/part-load conditions. The gradual shift to richer mixtures (1.2 to 1.0 equivalence ratio) as engine intake airflow increases (barring any converter/regulator influence) indicates that the DFA mixers' mixture control capability is somewhat affected by inlet air restriction. Such restrictions are caused by the inlet air-ducting, hot-air supply system and a dirty/wet/damaged air cleaner element, and they increase in magnitude with increasing engine speed and load (i.e., increased engine inlet airflow rate).

3.5/ Drivability

While no extensive drivability tests were performed, the vehicle exhibited no significant drivability problems with the mixer in place, using gasoline or propane. The switch from gasoline to propane and back was checked at elevated engine speed (about 2000 rpm) and was stall-free. No

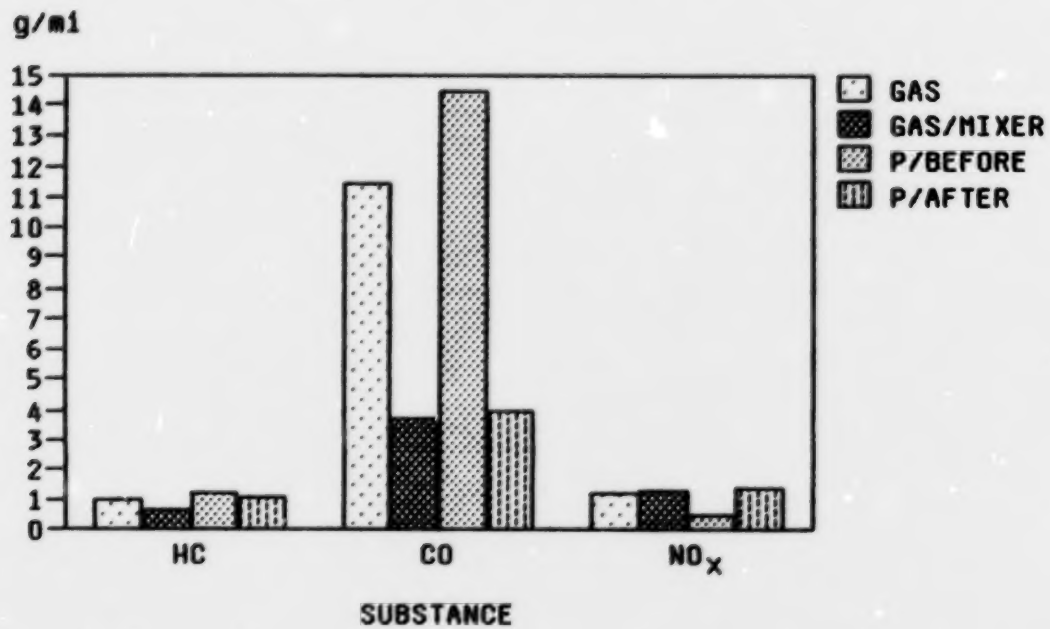


Figure 6/ CVS Exhaust Emissions —
Average Values

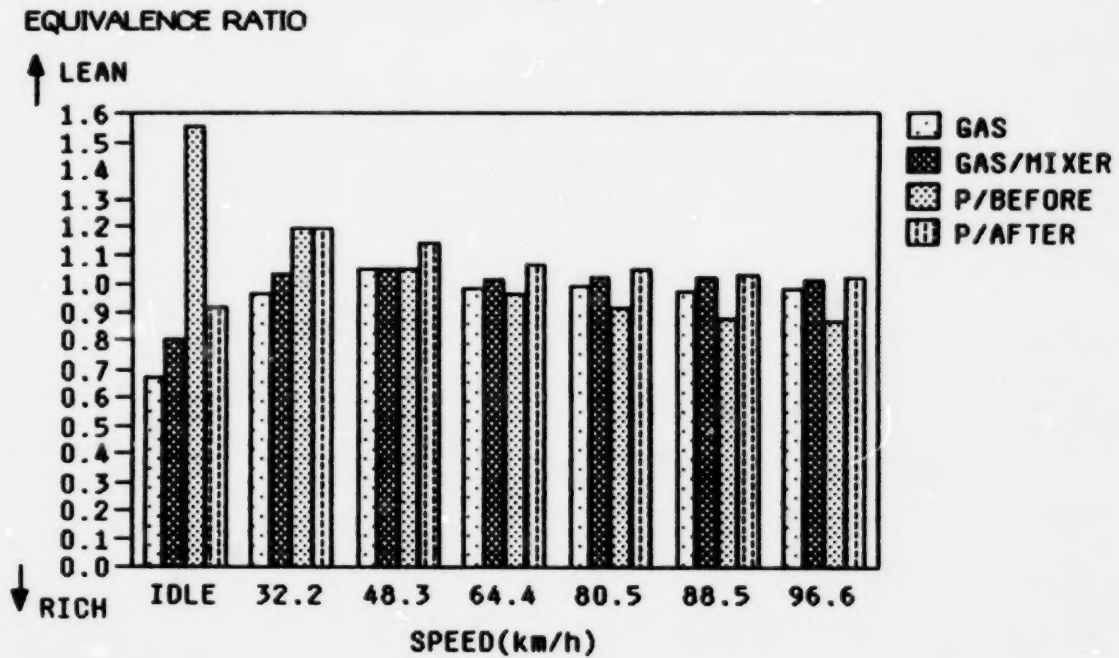


Figure 7/ A/F Equivalence Ratios —
Average Values

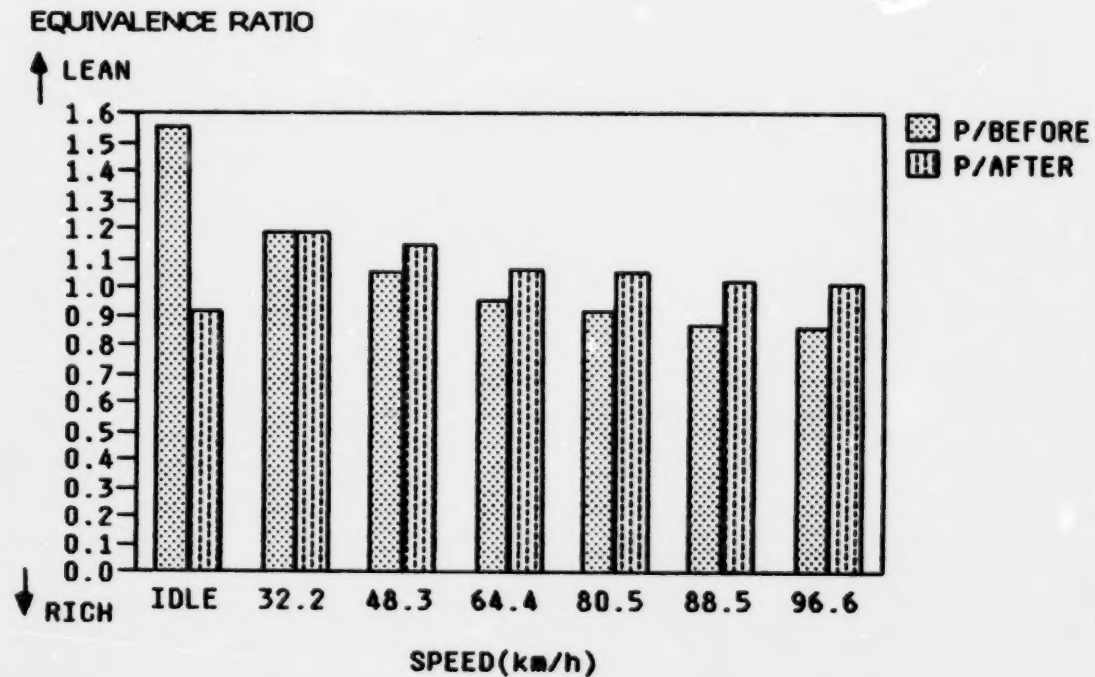


Figure 8/ A/F Equivalence Ratios —
Propane, Before/After Mixture Adjustment

significant transient problems, such as engine hesitations on acceleration, were observed.

3.6/ Spark Advance Curves

Spark advance was checked prior to initial distributor installation to ensure it met the manufacturers' specifications (Appendix K). The distributor calibration was within the proper limits for gasoline use. A comparison of the measured advance data was made to the Ford recommendations for dedicated propane conversion of the 4.9 L (300 CID) engine. This was intended to determine if the existing curve could be modified to optimize performance and fuel consumption when using propane.

From Figure 9 it is apparent that the mechanical advance curve is close to the Ford recommendations for propane. Figure 10, however, illustrates the low total vacuum advance of the stock distributor; therefore, some improvements are possible. The mixer manufacturer suggests advancing the initial timing by 2° crankshaft. Advancing the initial timing by a total of 4° crankshaft, or replacement of the vacuum advance assembly with a 4° higher total advance capability unit, would position the vacuum advance curve within the Ford propane recommendations. Spark knock when using gasoline would be a concern if this were done and would depend on the individual engine's octane requirement.

3.7/ Comparison with Other Equipment

The vehicle used in these tests was used previously to evaluate a number of propane conversion kits. While it is difficult to make a meaningful comparison with the old non-dual-fuel conversion results, a general feel for the results is possible.

The DFA conversion (see Appendix L for DFA mixer system), when properly set up, provides similar WOT performance as the more complex dedicated propane mixer (Figure 11). It should be noted that the vehicle performance on gasoline was much better in the previous testing (approximately 3 s faster at WOT acceleration of 0-96.5 km/h (0-60 mph). Performance comparisons between the DFA and previous conversions should be made relative to their respective baseline gasoline tests. Constant volume sampling (CVS) fuel consumption values, shown in Figure 12, indicate virtually identical fuel consumption was achieved as the dedicated propane mixer unit. This indicates that this particular vehicle conversion appears to have no significant penalty in fuel consumption, even with the dual-fuel capability. The DFA conversion demonstrated a 6% (urban) and 4% (highway) energy consumption reduction compared to the previous conversion.

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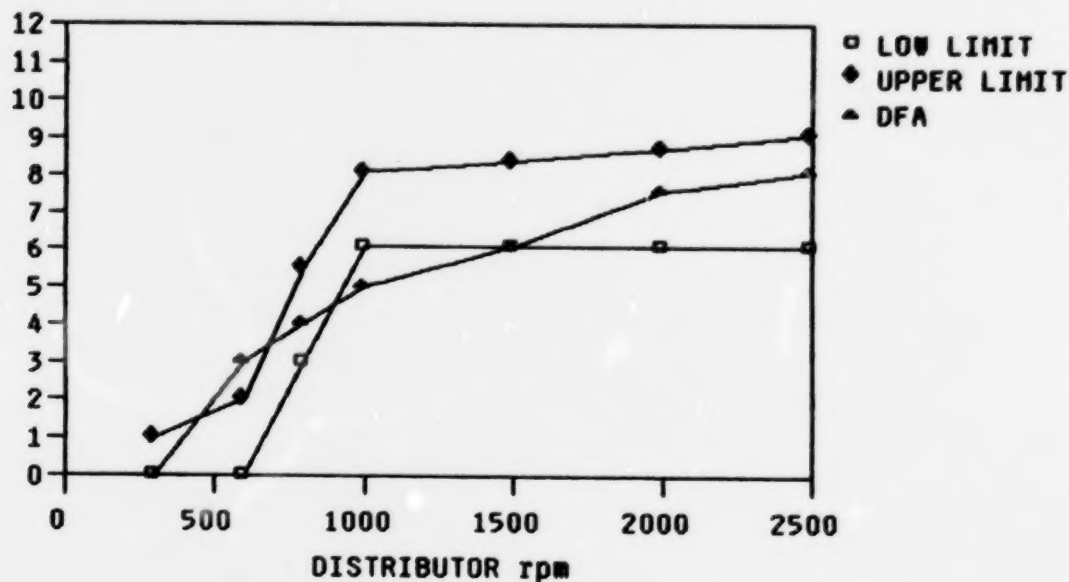


Figure 9/ Mechanical Spark Advance Data —
Propane, Recommended vs. Actual

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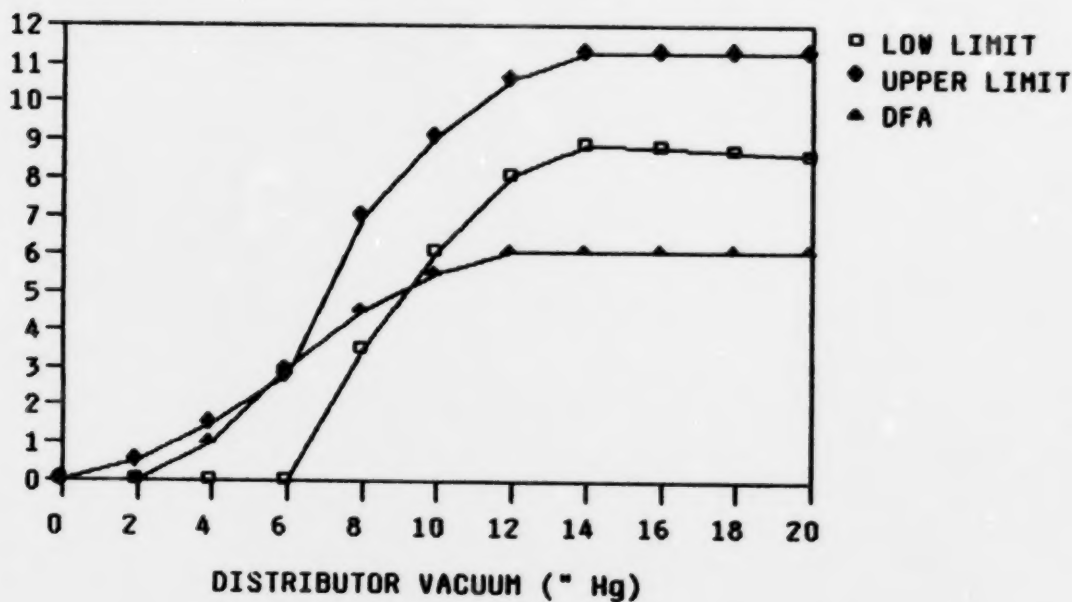


Figure 10/ Vacuum Spark Advance Data —
Propane, Recommended vs. Actual

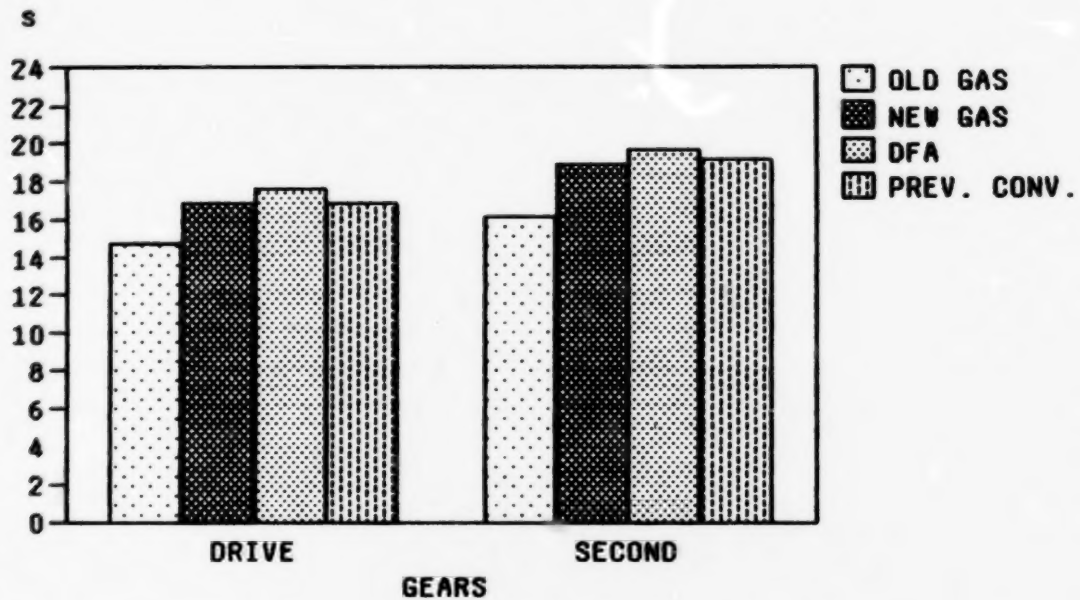


Figure 11/ Performance Data Comparison for
WOT Acceleration of 0-96.6 km/h (0-60 mph) —
Old Gas/New Gas/DFA/Previous Conversion

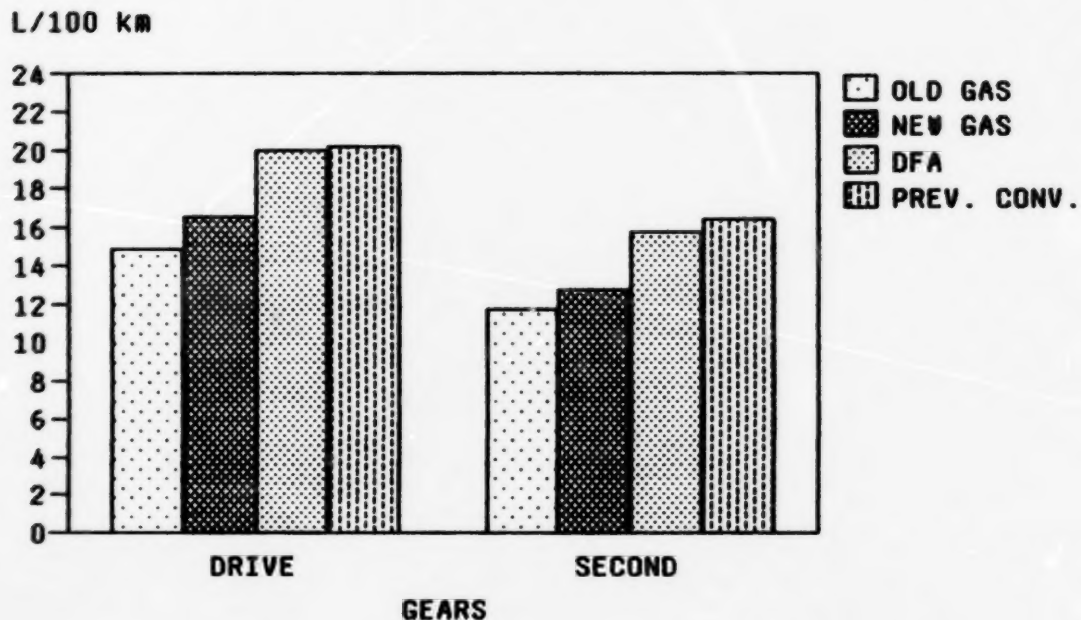


Figure 12/ Fuel Consumption Comparison —
Volumetric, Old Gas/New Gas/DFA/Previous Conversion

Equivalence ratio data were only available at idle, 48.3 km/h (30 mph), and 96.5 km/h (60 mph) on the previous conversion; thus, only a limited comparison is possible (Figure 13). Similar air/fuel ratio control was observed with both devices under light load conditions.

The previous conversion employed an initial spark advance setting of 14° BTDC, which was 2° ahead of the DFA conversion. It also had more mechanical advance, especially at low engine speeds (Figure 14). Both conversions used the same part number vacuum advance diaphragm and were found to have similar vacuum advance curves (Figures 15 and 16).

No exhaust emission comparisons were possible as the previous conversion had been tested with the exhaust gas recirculation (EGR) emission system disconnected.

The venturi-style dual-fuel mixers provide a substantial restriction to airflow, which has a noticeable effect on performance. Venturi mixers must be raised off the carburetor when gasoline is being used to minimize the disturbance of carburetor operation. The DFA design mixer does not suffer from these drawbacks, as evidenced by the lack of appreciable intake air restriction. The DFA mixer is fixed in place; there is no need for moving parts.

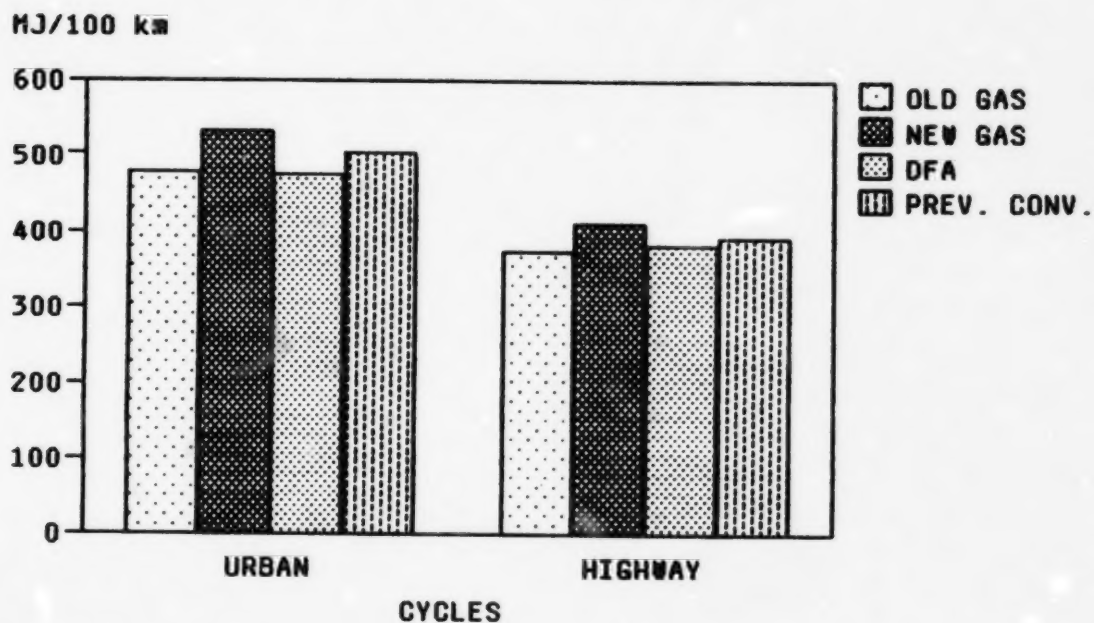


Figure 13/ Energy Consumption Comparison — Urban/Highway Cycles

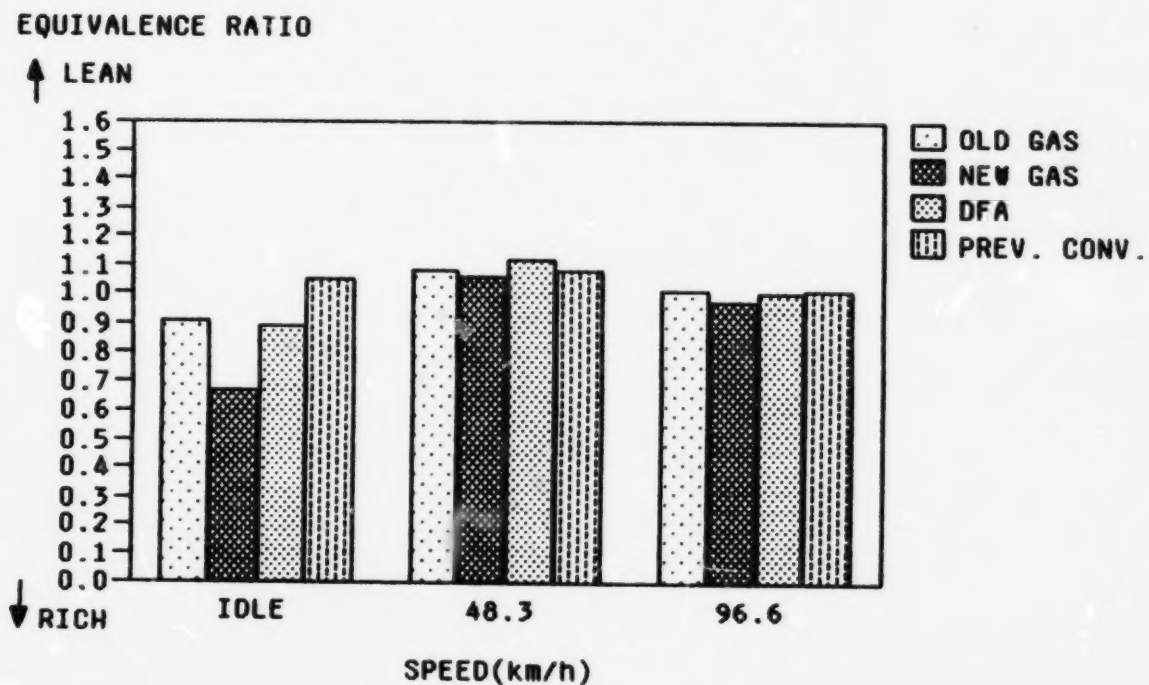


Figure 14/ A/F Equivalence Ratio Comparison — DFA vs. Previous Conversion

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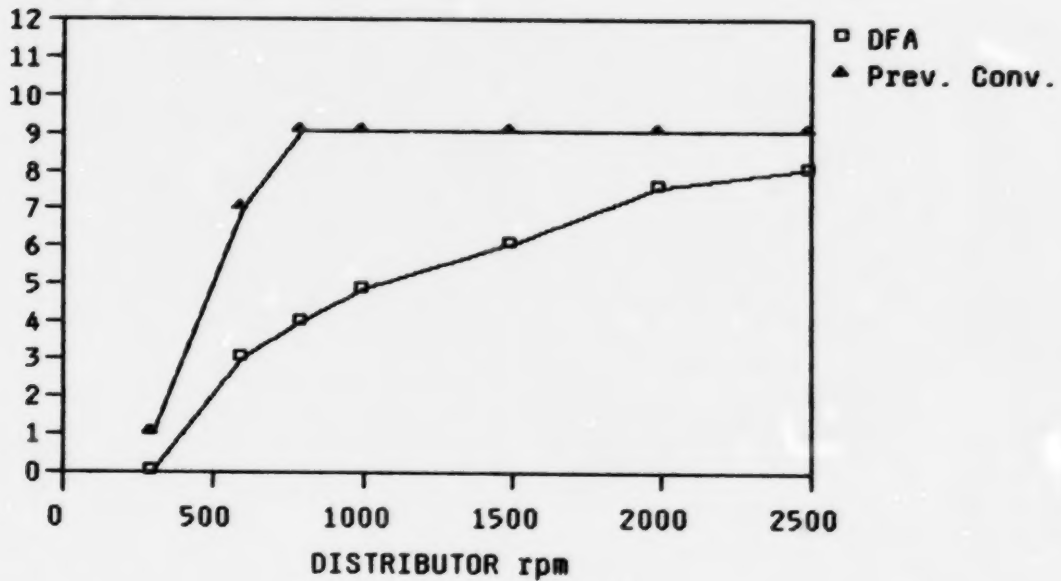


Figure 15/ Mechanical Spark Advance Comparison —
DFA vs. Previous Conversion

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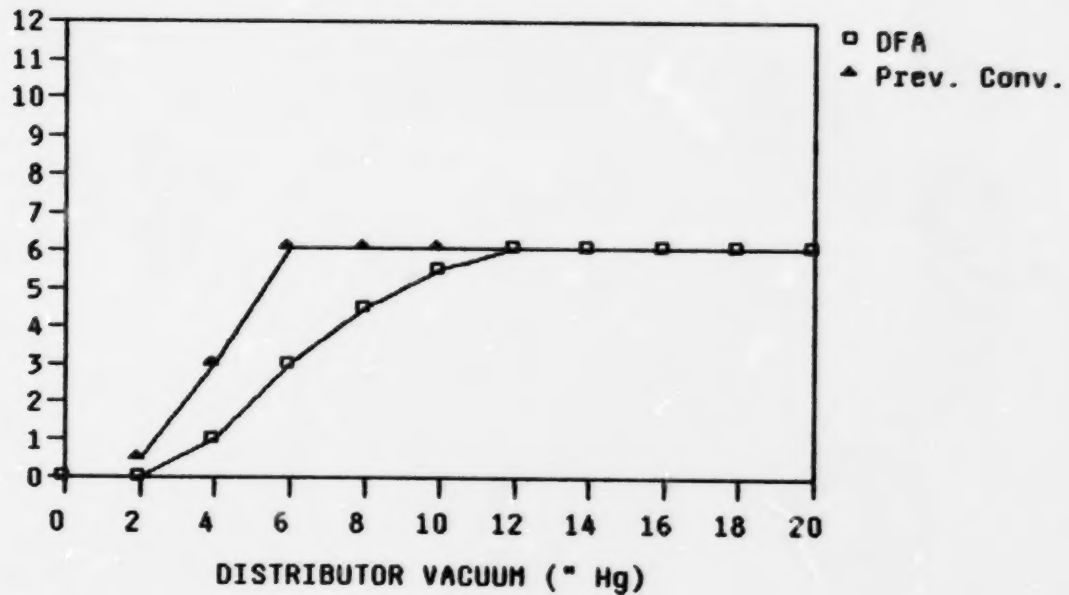


Figure 16/ Vacuum Spark Advance Comparison —
DFA vs. Previous Conversion

4/ CONCLUSIONS

- 1/ When using propane, WOT acceleration performance similar to the baseline gasoline case was experienced. Volumetric fuel consumption values were in the range typical of proper propane conversions. A slight improvement in average energy consumption was noted, again, typical of most proper propane conversions.
- 2/ After propane mixture adjustment, stoichiometric conditions were essentially maintained under the off-idle/part-load conditions tested.
- 3/ When using gasoline, no significant power loss was noted with the mixer in place. Wide open throttle manifold vacuum readings were in the 1.0 to 1.5 in. Hg range. Typical baseline gasoline values were in the 1.0 in. Hg range. This indicates that there was no significant restriction of airflow to the engine due to the mixer.
- 4/ In the particular test vehicle used (1981 Ford F150 six-cylinder pickup truck), the supplied mixer did not fit in the original equipment air cleaner. It was necessary to purchase the alternate design air cleaner assembly (\$200 Canadian) to allow the mixer to be installed. DFA should consider designing a mixer unit for the offset style air cleaner to eliminate this problem.
- 5/ Because there are no moving parts in the mixer, maintenance requirements would likely be minimal.

In summary, the DFA propane mixer is a functional device which has lived up to most of the manufacturer's claims as installed on the MTC test vehicle. It is important to note that this was a limited test program and the results cannot be generalized or extended. The mixer design concept appears promising and, with some further development, should be easily installed and maintained.

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APPENDIX A/ TEST VEHICLE DETAILS

APPENDIX A/ TEST VEHICLE DETAILS

Vehicle

Mfr.	Ford
Model	Custom F150
Year	1981
Serial number	2FTDF15E9BCA79819
GVW	2472 kg (5450 lb)
Curb wt.	1650 kg (3637 lb)
Trans	auto 3 speed (C6)
Tires	Firestone M/S P235/75R15
Tire pressures	310 kPa (45 psig)
Odometer	32 250 km

Engine

In-line six-cylinder
4.9 L (300 CID)
1 barrel carburetor (Carter YFA)

Emission Controls

Catalytic converter (conventional oxidation catalyst)
Exhaust gas recirculation (EGR)
Thermactor exhaust air injection
Evaporative emission system
Positive crankcase ventilation (PCV) system

Fuels

Regular unleaded gasoline
(CGSB Spec. CAN2-3.5-M79)

Propane (liquified petroleum gas [LPG])
(CGSB CAN2-3.14-M78)

(See Appendix C)

Dynamometer Settings

Inertia weight	1814 kg (4000 lb)
Road load @ 80 km/h (50 mph)	15.0 hp

APPENDIX B/ FACILITIES

APPENDIX B/ FACILITIES

The MTC chassis dynamometer facility consists of a Clayton ECE 50 twin-roll system (same as the model used at Transport Canada, Environment Canada, US EPA, and most major auto manufacturers for emissions and fuel economy testing) with custom digital controller. Exhaust emissions are collected and analysed using a Horiba Model 20 constant volume sampling (CVS) system. Hydrocarbon emissions are quantified using a Horiba OPE-408 flame ionization detector. Carbon dioxide and carbon monoxide concentrations are measured with a Horiba Model 105 non-dispersive infrared analyser. Oxides of nitrogen are measured by a Thermo Electron Corporation chemiluminescent analyser. Air/fuel equivalence ratios were obtained employing a Beckman Model 957 air/fuel ratio analyser. The data acquisition system employs a Hewlett-Packard 9825 desk top computer. Vehicle cooling is assisted by a large blower unit. The facility is calibrated on a regular basis, and weekly preventative maintenance is performed. A controlled-environment trailer is used for vehicle preconditioning/overnight soak. A separate facility, with a Sun diagnostic tester (infrared CO meter) and distributor tester, is used for vehicle setup and modification.

APPENDIX C/ FUEL SPECIFICATIONS

**NATIONAL
STANDARD
OF CANADA**

**NORME
NATIONALE
DU CANADA**

CAN2-3.5-M79

Supersedes/Remplace
3-GP-5Ma
3-GP-5

**Gasoline,
Automotive,
Unleaded**

**Essence,
Auto, sans
plomb**

**Canadian Government
Specifications Board**

**Office des normes du
gouvernement canadien**



This standard has been developed by the CANADIAN GOVERNMENT SPECIFICATIONS BOARD (CGSB) for the application stated in the Scope clause. The user of this standard is responsible for judging its suitability for his particular purpose or application.

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CAN2-3.5-M79
Supersedes/Remplace
3-GP-5Ma
3-GP-5

**NATIONAL
STANDARD
OF CANADA**

**NORME
NATIONALE
DU CANADA**

**GASOLINE, AUTOMOTIVE,
UNLEADED**

**ESSENCE, AUTO,
SANS PLOMB**

This standard is expressed in SI (Metric) units in response to the requirements of Canada's metric conversion program. By agreement with the Committee on Petroleum Products it supersedes 3-GP-5Ma and 3-GP-5 which expressed the requirements in yard/pound units.

Les valeurs de la présente norme sont exprimées en unités SI (métriques) conformément aux exigences du Programme canadien de conversion au système métrique. Le comité des Produits pétroliers est d'accord que la présente remplace la norme 3-GP-5Ma et (F)3-GP-5 dont les valeurs étaient exprimées en unités verge-livre.

Prepared by



**Specifications
Board**

Approved by



**Standards Council
of Canada**

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**l'Office
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**Conseil canadien
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Publiée, mai 1979, par
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**CANADIAN GOVERNMENT SPECIFICATIONS BOARD
OFFICE DES NORMES DU GOUVERNEMENT CANADIEN**

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La présente Norme nationale du Canada a été traduite en français par le Bureau des traductions du Secrétariat d'État. La révision technique de cette traduction a été assurée par la Direction de la gestion des données sur le matériel du ministère des Approvisionnements et Services.

CAN2-3.5-M79

Supersedes/Remplace
3-GP-5Ma
3 GP-5

**CANADIAN GOVERNMENT
SPECIFICATIONS BOARD**

Standard for

**GASOLINE, AUTOMOTIVE,
UNLEADED**

**OFFICE DES NORMES DU
GOUVERNEMENT CANADIEN**

Norme

**ESSENCE, AUTO,
SANS PLOMB**

1. SCOPE

This standard applies to two types of gasoline to which no lead or phosphorus have been added and are therefore suitable for use under all climatic conditions in spark ignition engines equipped with emission control systems requiring the use of unleaded gasoline. In the interest of conservation of petroleum products it is essential that engine manufacturers continue to design engines to operate on Type 2 gasoline. Type 1 is then reserved for cases where octane requirement increase in use is such that a higher octane gasoline is required to prevent excessive knock.

2. APPLICABLE PUBLICATIONS

- 2.1 The following publications are applicable to this standard:
- 2.1.1 American Society for Testing and Materials (ASTM)
- Annual Standards for Petroleum Products and Lubricants
- E 29 — Recommended Practice for indicating which places of figures are to be considered significant in specified limiting values
- 2.2 Reference to the above publication is to the latest issues.

3. CLASSIFICATION

- 3.1 The gasoline shall be supplied in the following types and grades as specified (par. 7.1):
- 3.1.1 *Types*
- Type 1*
Type 2
- 3.1.2 *Grades*
- Summer* — (Supplied 1 May to 30 September inclusive)

OBJET

La présente norme s'applique à deux types d'essence sans plomb ni phosphore destinée à être utilisée dans les moteurs à allumage par bougies munis de systèmes antipollution à essence sans plomb, fonctionnant dans toutes les conditions climatiques. Afin de promouvoir la conservation des produits pétroliers, il est indispensable que les fabricants de moteurs continuent à concevoir des moteurs fonctionnant au moyen de l'essence de type 2. Le type 1 est utilisé dans les cas où l'on préconise un indice d'octane plus élevé afin de prévenir les détonations excessives.

PUBLICATIONS APPLICABLES

- Les publications suivantes s'appliquent à la présente norme:
- American Society for Testing and Materials (ASTM)
- Annual Standards for Petroleum Products and Lubricants
- E 29 — Recommended Practice for indicating which places of figures are to be considered significant in specified limiting values

Ces publications s'entendent de l'édition la plus récente.

CLASSIFICATION

- L'essence doit être fournie dans les types et grades suivants, selon les prescriptions (par. 7.1):
- Types*
- Type 1*
Type 2
- Grades*
- Été* — (Fourni entre le 1^{er} mai et le 30 septembre inclusivement)

Winter — (Supplied 1 October to 30 April inclusive)

Hiver — (Fourni entre le 1^{er} octobre et le 30 avril inclusivement)

4. GENERAL REQUIREMENTS

- 4.1 The gasoline shall be clear, and free from undissolved water and suspended matter.
- 4.2 The gasoline shall be colored as follows:
- Type 1 — Green
Type 2 — Undyed

The dye concentration of Type 1 gasoline shall be approximately 4.5 kg/1000 m³.

EXIGENCES GÉNÉRALES

- L'essence doit être limpide et exempte d'eau non dissoute et de matières en suspension.
- L'essence doit avoir la couleur suivante :
- Type 1 — Vert
Type 2 — Incolore

La concentration en colorant de l'essence de type 1 doit être environ 4.5 kg/1000 m³.

5. DETAIL REQUIREMENTS

NOTICE: The gasoline shall comply with requirements below, the limits of which are absolute, and not subject to correction for tolerance of test methods (par. 6.2).

EXIGENCES PARTICULIÈRES

REMARQUE: L'essence doit être conforme aux exigences suivantes dont les limites sont absolues et ne peuvent être corrigées pour tenir compte des tolérances des méthodes d'essai (par. 6.2).

		Type 1 and/or Type 2			
		Summer Été	Winter Hiver	Test Method Méthode d'essai	
5.1	Distillation			ASTM D 86	Distillation
5.1.1	10% evaporated, °C Max.	57	52		Évaporation 10%, °C Max.
5.1.2	50% evaporated, °C Max.	118	113		Évaporation 50%, °C Max.
5.1.3	90% evaporated, °C Max.	185	185		Évaporation 90%, °C Max.
5.2	Reid Vapor Pressure, kPa Min. Max.	— 76	62 97 (Note 1)	ASTM D 323 (Remarque 1)	Tension de vapeur, méthode Min. de Reid, kPa Max.
5.3	Lead Content, mg/L, Max.	13	13	ASTM D 3237 or/ou EPS 1-AP-73-3*	Teneur en plomb, mg/L, Max.
5.4	Phosphorus Content (as P), mg/L, Max.	1.3	1.3	ASTM D 3231 or/ou EPS 1-AP-73-4*	Teneur en phosphore (en P), mg/L, Max.
5.5	Manganese Content (as Mn), mg/L, Max.	18	18	ASTM D3831	Teneur en manganèse (en Mn), mg/L, Max.
5.6	Sulfur (Lamp), % mass, Max.	0.15	0.15	ASTM D 1266	Soufre (méthode de la lampe), % en masse, Max.
5.7	Gum, Existent, mg/100 mg	7	7	ASTM D 381	Gommes existantes, mg/100 mg
5.8	Oxidation Stability (induction period), min (at refinery Min.)	240	240	ASTM D 525	Stabilité à l'oxydation (période d'admission), min (à la raffine- rie Min.)
5.9	Corrosion (Copper strip-test tube) 3 h at 50°C, Max.	No./No 1	No./No 1	ASTM D 130	Corrosion (lame de cuivre/éprou- vette) 3 h à 50°C, Max.

NOTE 1: Except that during the interval 1 November to 28 February the maximum RVP shall not exceed 103 kPa.

REMARQUE 1: Toutefois, pendant la période s'étendant du 1^{er} novembre au 28 février, la tension de vapeur maximale ne doit pas dépasser 103 kPa.

*These methods are equivalent to the ASTM methods.

*Ces méthodes équivalent aux méthodes de l'ASTM.

- 5.10 **Anti-knock Quality** — The Motor Octane number (M) and the anti-knock (octane) index (defined as half the sum of the Research (R) and Motor (M) octane numbers) shall be not less than:

	Type 1		Type 2	
	$\frac{R + M^*}{2}$	M*	$\frac{R + M^*}{2}$	
Eastern Canada (including all of Ontario) and Coastal British Columbia	90.0	82.0	87.0	Est du Canada (y compris tout l'Ontario) et la côte de la Colombie-Britannique
Manitoba and Saskatchewan	88.0	80.0	85.0	Manitoba et Saskatchewan
Alberta, Interior British Columbia, Yukon Territory and Northwest Territories	87.0	79.0	84.0	Alberta, intérieur de la Colombie-Britannique, Territoires du Yukon et du Nord-Ouest
	ASTM D 2699	and/et	D 2700	

6. INSPECTION

- 6.1 **Sampling** — A sample of not less than 4 L shall be obtained in accordance with ASTM D 270.
- 6.2 **Assessment of Conformance to the Standard** — For tests carried out by the inspection laboratory, average results shall be used if multiple determinations are made. For those test methods where repeatability data are given, the average value derived from the individual results that agree within the repeatability limits may be used at the discretion of the Inspection Authority, provided an indication is given of the total number of results obtained and of the number falling outside the repeatability limits. To determine conformance with each requirement, an observed value or calculated value shall be rounded off to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off procedure given in ASTM E 29.

7. NOTES

Options — The following options provided in this standard should be specified in application of the standard.

- Type (par. 3.1.1)
- Grade (par. 3.1.2)
- If in any particular locality the grade (Summer or Winter) commercially available at the time of purchase is not acceptable, then purchase documents should state the grade required.

*Motor Rating and $\frac{R + M}{2}$ values shall be taken as determined to the nearest 0.1 Octane.

INSPECTION

Échantillonnage — Un échantillon d'au moins 4 L doit être prélevé conformément à la méthode D 270 de l'ASTM.

Évaluation de la conformité à la norme — Si le laboratoire d'inspection procède à des mesures répétées, il faudra prendre les valeurs moyennes, sauf lorsque des limites de répétabilité sont spécifiées dans les méthodes d'essai. Dans ce dernier cas on pourra utiliser, avec l'autorisation des services officiels d'inspection, la valeur moyenne obtenue à partir des résultats tombant dans les limites de répétabilité, à condition d'indiquer le nombre total de mesures effectuées et le nombre tombant hors des limites de répétabilité. Pour établir la conformité aux exigences, les valeurs observées ou calculées doivent être arrondies à l'unité la plus proche, pour le dernier chiffre de droite des nombres utilisés pour exprimer la valeur limite selon E 29 de l'ASTM.

REMARQUES

Options — Les options suivantes qui sont prévues dans la présente norme, devraient être précisées lors de son application:

- Type (al. 3.1.1)
- Grade (al. 3.1.2)
- Si dans toute région donnée le grade (été ou hiver) vendu dans le commerce au moment de l'achat n'est pas acceptable, les documents d'achat devront préciser le grade exigé.

* Les valeurs de l'indice d'octane moteur et de $\frac{R + M}{2}$ doivent être arrondies au dixième (0.1) le plus proche de l'indice d'octane.

7.3

The publications listed in par. 2.1.1 may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103, U.S.A.

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**NORME
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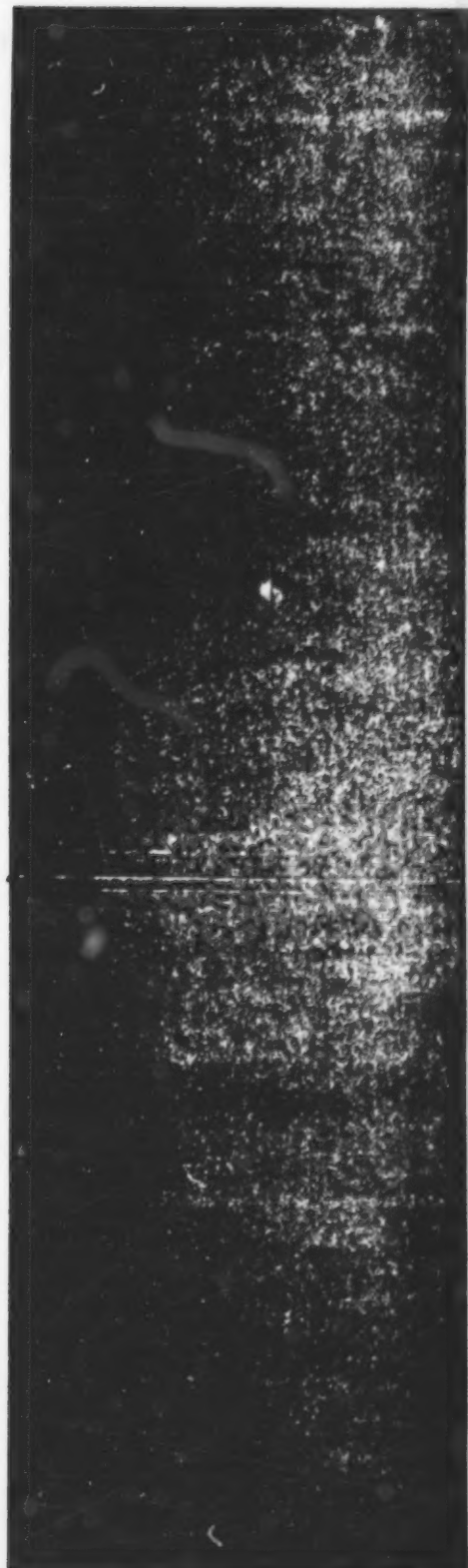
CAN2-3.14-M78

**Liquefied
Petroleum
Gas (Propane)**

**Gaz de
pétrole
liquéfié
(propane)**

**Canadian Government
Specifications Board**

**Office des normes du
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NATIONAL
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NORME
NATIONALE
DU CANADA

LIQUEFIED PETROLEUM
GAS (PROPANE)

GAZ DE PÉTROLE
LIQUÉFIÉ (PROPANE)

This standard is expressed in SI (Metric) units in response to the requirements of Canada's metric conversion program. It does not supersede the yard/pound version, which will be maintained as 3-GP-14 until no longer required.

Les valeurs de la présente norme sont exprimées en unités SI (métriques) conformément aux exigences du Programme canadien de conversion au système métrique. Elle ne remplace pas la version verge-livre qui restera en vigueur aussi longtemps que la norme (F)3-GP-14 sera nécessaire.

Prepared by



Specifications
Board

Préparée par



l'Office
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Approved by



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Conseil canadien
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**CANADIAN GOVERNMENT
SPECIFICATIONS BOARD**

**OFFICE DES NORMES DU
GOUVERNEMENT CANADIEN**

Standard for

Norme

**LIQUEFIED PETROLEUM GAS
(PROPANE)**

**GAZ DE PÉTROLE LIQUÉFIÉ
(PROPANE)**

1. SCOPE

- 1.1 This standard applies to two grades of hydrocarbon product consisting essentially of liquid propane.
- 1.2 For information on uses see par. 7.2.

OBJET

La présente norme s'applique à deux grades d'un produit aux hydrocarbures constitué essentiellement de propane liquide.

Voir au par. 7.2 des précisions sur l'emploi du produit.

2. APPLICABLE PUBLICATIONS

- 2.1 The following publications are applicable to this standard:
 - 2.1.1 Canadian Government Specifications Board (CGSB)
 - 3-GP-0 — Methods of Testing Petroleum and Associated Products
 - 2.1.2 American Society for Testing and Materials (ASTM)
 - Annual Standards on Petroleum Products and Lubricants
 - E 29 — Recommended Practice for Indicating which Places of Figures are to be Considered Significant in Specified Limiting Values
 - 2.1.3 Gas Processors Association (GPA)
 - GPA Publication 2140 — GPA Liquefied Petroleum Gas Specifications and Test Methods.
- 2.2 Reference to the above publications is to the latest issues.

PUBLICATIONS APPLICABLES

Les publications suivantes s'appliquent à la présente norme:

Office des normes du gouvernement canadien (ONGC)

3-GP-0 — Méthodes d'essai des produits pétroliers et produits connexes.

American Society for Testing and Materials (ASTM)

Annual Standards on Petroleum Products and Lubricants

E 29 — Recommended Practice for Indicating which Places of Figures are to be Considered Significant in Specified Limiting Values

Gas Processors Association (GPA)

GPA Publication 2140 — GPA Liquefied Petroleum Gas Specifications and Test Methods.

Ces publications s'entendent de l'édition la plus récente.

3. CLASSIFICATION

- 3.1 The liquefied petroleum gas shall be supplied in the following grades, as specified (par. 7.1):
 - 3.1.1 *Grades*
 - Grade 1* — For use in spark ignition engines (par. 7.2.1)
 - Grade 2* — For use in other than spark ignition engines (par. 7.2.2)

CLASSIFICATION

Le gaz de pétrole liquéfié conforme à la présente norme doit être livré dans les grades suivants, selon les prescriptions (par. 7.1):

Grades

Grade 1 — Pour moteurs à explosion (al. 7.2.1)

Grade 2 — Autre que pour moteurs à explosion (al. 7.2.2)

4. GENERAL REQUIREMENTS

- 4.1 The liquefied petroleum gas shall consist chiefly of propane.
- 4.2 The gas shall be odorized to ensure that it is readily detectable in the atmosphere at all concentrations of one-fifth of the lower explosive limit and above (par. 7.3).
- 4.2.1 The requirement for odorization shall be considered to be met by the use of 1.0 kg of ethyl mercaptan, 1.0 kg of thiophene* or 1.4 kg of amyl mercaptan per 83 m³ of liquefied petroleum gas at 15°C and 101.325 kPa. Other odorants may be used, provided they meet the stated odorization requirement.

NOTE: If specified (par. 7.1), for applications where the odorant would serve no useful purpose as a warning agent, this requirement may be waived, unless it is required by legal ordinances.

- 4.3 The liquefied petroleum gas shall be free from harmful quantities of deleterious substances.

5. DETAIL REQUIREMENTS

The fuel shall comply with the following detail requirements, *the limits of which are absolute and not subject to correction for tolerances of test methods* (par. 6.2).

EXIGENCES GÉNÉRALES

Le gaz de pétrole liquéfié doit être constitué principalement de propane.

Un odorisant doit être incorporé au gaz de sorte que celui-ci soit facile à déceler lorsqu'il est présent dans l'atmosphère, à toutes les concentrations égales ou supérieures à un cinquième de la limite inférieure d'explosion (par. 7.3).

Pour satisfaire à l'exigence d'odorisation, 1.0 kg d'éthylmercaptan, 1.0 kg de thiophène* ou 1.4 kg d'amylmercaptan doivent être incorporés à 83 m³ de gaz de pétrole liquéfié à une température de 15°C et sous une pression de 101.325 kPa. D'autres odorisants peuvent être utilisés à condition qu'ils satisfassent à l'exigence d'odorisation prescrite.

REMARQUE: En cas de prescription (par. 7.1) et lorsque l'odorisant est inutile comme agent avertisseur, la présente exigence peut être exclue, à moins qu'elle ne soit imposée par la loi.

Le gaz de pétrole liquéfié ne doit pas contenir de substances délétères en quantités nocives.

EXIGENCES PARTICULIÈRES

Le combustible doit être conforme aux exigences particulières suivantes *dont les valeurs limites sont absolues et ne peuvent être corrigées pour tenir compte des tolérances des méthodes d'essai* (par. 6.2).

		Grade 1		Grade 2		Test Method ASTM Méthode d'essai	
		Min.	Max.	Min.	Max.		
5.1	Composition, liq vol %						Composition, % en volume liquide
	Propane	90	—	**	**	D 2163***	Propane
	Propylene	—	5.0	**	**		Propylène
	Butane & heavier hydrocarbons	—	2.5	—	2.5		Butane et hydrocarbures plus lourds
5.2	Vapor Pressure at 37.8°C, kPa	—	1435	—	1435	D 2598 ^{or} ou D 1267	Tension de vapeur à 37.8°C kPa
5.3	Motor Octane Number	95	—	—	—	D 2598 ^{or} ou D 2623	Indice d'octane
5.4	Sulfur (Lamp), mg/m ³ of vapour at 15°C and 101.325 kPa	—	230	—	345	D 2784	Soufre (Lampe) mg/m ³ de vapeur à 15°C et sous 101.325 kPa
5.5	Corrosion, (Copper Strip)	—	No. 1	—	No. 1	D 1838	Corrosion (lame de cuivre)

*Frequently referred to as thiophene.

**Grade 2 composition for propane/propylene content may be established by contractual agreement between the supplier and the purchaser, subject further to the following detailed requirements.

***Using the Hexylmethylphosphoramid column shown in table 2 of ASTM D 2163.

*Désigné fréquemment thiophène.

**Les pourcentages propane/propylène dans le gaz de grade 2 peuvent être établis par un accord contractuel entre le fournisseur et l'acheteur, sous réserve des exigences particulières qui suivent.

***Prendre la colonne de l'hexaméthylphosphoramid du tableau 2 de la norme ASTM D 2163.

- 5.6 **Residual Matter** — The residue on evaporation of 100 mL shall not exceed 0.05 mL. An acceptable product shall not yield a persistent oil ring (stain) when 0.3 mL of solvent-residue mixture is added to filter paper in 0.1 mL increments and examined in daylight after 2 min.

ASTM D 2158

- 5.7 **Hydrogen Sulfide** — The product shall not cause a distinct coloration of the lead acetate test paper.

ASTM D 2420

- 5.8 **Dryness** — The product shall be dry when tested in accordance with the Cobalt Bromide Method (3-GP-0, Method 10.7). Alternatively, the dew point shall not be higher than -25°C when determined in accordance with 3-GP-0, Method 10.10.

6. INSPECTION

- 6.1 **Sampling** — A sample of the size required by the testing laboratory shall be provided in accordance with ASTM D 1265.

- 6.2 **Assessment of Conformance to the Standard** — In respect to tests carried out by the inspection laboratory, average results shall be used if multiple determinations are made. For those test methods where repeatability data are given, the average value derived from the individual results that agree within the repeatability limits may be used at the discretion of the Inspection Authority, provided an indication is given of the total number of results obtained, and of the number falling outside the repeatability limits. For purposes of determining conformance with each requirement, an observed value shall be rounded off to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off procedure given in ASTM E 29.

7. NOTES

- 7.1 **Option** — The following option provided in this standard should be specified in application of the standard.

a. Grade of gas (par. 3.1).

7.2 Intended Uses

- 7.2.1 Grade 1 liquefied petroleum gas fuel covered by this standard is intended for use in spark ignition engines as employed in fork lift trucks in depots. It is particularly applicable for consumption in local fleet operations. This grade is equivalent to the Propane HD-5

Résidus — Les résidus de l'évaporation de 100 mL du produit ne doivent pas dépasser 0.05 mL. Un papier filtre soumis à une addition progressive de 0.3 mL de mélange solvant-résidu à raison de 0.1 mL à la fois ne doit pas présenter de cerne huileux persistant (tâche) lorsqu'il est examiné à la lumière du jour 2 min après l'addition du mélange.

ASTM D 2158

Hydrogène sulfuré — Le produit ne doit pas causer une coloration prononcée du papier à l'acétate de plomb.

ASTM D 2420

Siccité — Le produit doit s'avérer sec à l'essai effectué conformément à la méthode du bromure de cobalt (méthode 10.7, 3-GP-0) ou il doit présenter un point maximal de rosée de -25°C déterminé conformément à la méthode 10.10 de la norme 3-GP-0.

INSPECTION

Échantillonnage — Un échantillon du volume prescrit par le laboratoire d'essai doit être fourni; il doit être prélevé conformément à D 1265 de l'ASTM.

Évaluation de la conformité à la norme — Si le laboratoire d'inspection procède à des mesures répétées, il faudra prendre les valeurs moyennes, sauf lorsque des limites de répétabilité sont spécifiées dans les méthodes d'essai. Dans ce dernier cas on pourra utiliser, avec l'autorisation des services officiels d'inspection, la valeur moyenne obtenue à partir des résultats tombant dans les limites de répétabilité, à condition d'indiquer le nombre total de mesures effectuées et le nombre tombant hors des limites de répétabilité. Pour établir la conformité aux exigences, les valeurs observées ou calculées doivent être arrondies à l'unité la plus proche, pour le dernier chiffre de droite des nombres utilisés pour exprimer la valeur limite selon E 29 de l'ASTM.

REMARQUES

Option — L'option suivante qui est prévue dans la présente norme devrait être précisée lors de son application:

a. Grade de gaz (par. 3.1).

Utilisations prévues

Le gaz de pétrole liquéfié de grade 1 conforme à la présente norme est destiné aux moteurs à explosion tels que ceux dont sont équipés les chariots élévateurs à fourche dans les entrepôts. Il convient particulièrement pour les véhicules utilisés localement. Cette

shown in the Gas Processors Association (GPA) Publication 2140.

classe de gaz équivaut au propane HD-5 mentionné dans la publication 2140 de la Gas Processors Association (GPA).

7.2.2 Grade 2 liquefied petroleum gas fuel covered by this standard is intended for uses other than in spark ignition engines. It is particularly applicable for consumption in domestic heating and cooking units and in industrial heating and processing where the composition of the products of combustion may be critical.

Le gaz de pétrole liquéfié de grade 2 conforme à la présente norme est destiné à d'autres utilisations que les moteurs à explosion. Il convient particulièrement aux appareils domestiques de chauffage et de cuisson ainsi qu'aux installations industrielles de chauffage et de traitement où la composition des produits de la combustion a une importance primordiale.

7.3 The maximum sulfur contributed by the odorants in par. 4.2.1 is 23 mg/m³.

La teneur maximale en soufre attribuable aux odorants décrits à l'al. 4.2.1 est de 23 mg/m³.

7.4 The publication listed in par. 2.1.1 may be obtained from the Canadian Government Specifications Board.

La publication mentionnée à l'al. 2.1.1 est diffusée par l'Office des normes du gouvernement canadien.

7.5 The publications listed in par. 2.1.2 may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103, U.S.A.

Les publications mentionnées à l'al. 2.1.2 sont diffusées par l'American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103, U.S.A.

7.6 The publication listed in par. 2.1.3 may be obtained from the Gas Processors Association, 1812 First Place, Tulsa, Okla., 74103.

La publication mentionnée à l'al. 2.1.3 est diffusée par the Gas Processors Association, 1812 First Place, Tulsa, Okla., 74103.

APPENDIX D/ THE EPA/CVS TEST CYCLES

APPENDIX D/ THE EPA/CVS TEST CYCLES

The motor vehicle constant volume sampling (CVS) test methods are applicable to all light-duty vehicles. They are performed on a chassis dynamometer according to specific guidelines. The urban cycle test requires a preconditioning run, which consists of vehicle operation through the urban cycle, followed by a minimum 12 h soak at 20 to 22°C (68 to 72°F).

The dynamometer power absorption setting is adjusted to reproduce road load power at 80 km/h (50 mph) true speed (includes dynamometer friction). It is determined from equivalent inertia weight, reference frontal area, body shape, vehicle protuberances, and tire type.

D.1/ TC/EPA Urban Emissions and Fuel Consumption Cycle

The test vehicle is driven through a standard driving cycle as prescribed by Transport Canada (TC) and US EPA. The urban cycle consists of accelerations to various speeds, cruise periods, decelerations, and idle times. The cycle is traced on a moving chart recorder, with the driver making throttle adjustments so that the pen follows the cycle trace within a required tolerance. The first 505 s constitute the "cold transient" phase. The second, "stabilized," phase continues to the 1371 s mark. The engine is shut off for 10 min, after which the first 505 s are repeated ("hot transient" phase). Exhaust gases from each test phase are collected at the tail pipe, diluted with a known quantity of ambient air, and fed to three of the sample bags. This dilute mixture is sampled along with ambient air and analysed for emissions and fuel consumption. The urban cycle results represent the weighted averages of the three phases.

Test cell temperature is maintained in the 20 to 30°C range (23 to 25°C, typically). Temperature, barometric pressure, and humidity are recorded during the test for data correction purposes.

D.2/ Highway Fuel Economy Test (HWFET)

The vehicle is driven through the prescribed highway cycle, which is 765 s in duration. The highway cycle is performed, first to precondition the vehicle, and then repeated after 15 s of idle. During the second run, the exhaust gases are diluted with ambient air and collected in the fourth bag for analysis. Fuel consumption is then calculated using the carbon balance technique.

APPENDIX E/ ERROR CALCULATIONS

APPENDIX E/ ERROR CALCULATIONS

CVS Fuel/Energy Consumption

Measurement Error Range - 6% of value

$$- 0.06 \times 18 = 1.08 \text{ L/100 km}$$

Day-to-Day Variability - 0.5 L/100 km (observed maximum)

Total Error Range Estimate = 1.6 L/100 km

Gasoline Energy Equivalent = $1.6 \times 32.2 = 52 \text{ MJ/100 km}$

Propane Energy Equivalent = $1.6 \times 23.6 = 38 \text{ MJ/100 km}$

CVS Exhaust Emissions

Measurement Error Range - 6% of value

$$- 0.06 \times 14 = 0.84 \text{ g/mi (CO P-BEF)}$$

$$- 0.06 \times 5 = 0.30 \text{ g/mi (CO P-AFT)}$$

$$- 0.06 \times 1 = 0.06 \text{ g/mi (HC, NO}_x\text{)}$$

Day-to-day Variability - 0.3 g/mi (CO)

$$- 0.1 \text{ g/mi (HC, NO}_x\text{)}$$

Total Error Range Estimate - 1.1 g/mi (CO P-BEF)

$$- 0.6 \text{ g/mi (CO P-AFT)}$$

$$- 0.16 \text{ g/mi (HC, NO}_x\text{)}$$

Air/Fuel Equivalence Ratios

Measurement Error Range - 0.2 air/fuel ratio

$$\text{(near stoichiometry)} \quad - \frac{0.20}{14.7} = 0.014 \text{ gasoline equivalence ratio}$$

$$- \frac{0.20}{15.6} = 0.013 \text{ propane equivalence ratio}$$

Day-to-Day Variability - 0.070 equivalence ratio (maximum)

Total Error Range Estimate = 0.084 equivalence ratio

Dynamometer Performance Tests

Measurement Error Range - 0.5 s

Day-to-Day Variability - 1.0 s

Total Error Range Estimate = 1.5 s

Spark Advance Curve Data

Measurement Error Range - 1.0 distributor degrees
(distributor tester)

- 2.0 crankshaft degrees
(timing light)

Ignition System Variability - unknown, but perceived
to be less than 1.0
distributor degrees

Total Error Range Estimate - 1.5 distributor degrees

APPENDIX F/ PERFORMANCE DATA

APPENDIX F/ PERFORMANCE DATA

WOT Acceleration (0-96.5 km/h [60 mph])(s)

CONFIGURATION	DRIVE GEAR test#			SECOND GEAR test#		
	1	2	3	1	2	3
Baseline	17.1	17.2	17.2	19.1	19.0	19.1
Gasoline	16.7	16.4	16.5	18.2	18.2	18.1
" "	16.9	17.0	17.1	18.6	18.5	18.9
Gasoline	17.0	17.0	17.0	19.2	18.9	19.2
with	17.3	17.3	17.2	19.2	19.2	19.2
Mixer	17.4	17.3	17.3	19.3	19.2	19.2
" "	16.7	16.9	16.9	18.5	18.5	18.5
Propane	18.6	18.7	18.9	21.0	21.0	20.8
Before	18.5	18.5	18.7	20.7	20.5	20.7
Propane	18.1	18.0	18.0	19.4	19.8	19.8
After	17.3	17.3	17.2	19.1	19.0	19.3
Prev.Conv.*	14.8			16.7		
Old Gas **	14.8			16.0		

Notes: *Average of 6 tests

**Average of 3 tests

Average WOT Manifold Vacuum Data (in. Hg)

Gasoline	1.0	Propane Before Adjustment	1.5
Gas+Mixer	1.2	Propane After Adjustment	1.5

APPENDIX G/ ENERGY CONSUMPTION CALCUALTIONS

APPENDIX G/ ENERGY CONSUMPTION CALCULATIONS

	GASOLINE	PROPANE
Energy Content (wt.)	43.5 MJ/kg	46.3 MJ/kg
Specific Gravity(@0°C)	0.74 kg/L	0.51 kg/L
Liquid Energy Content	32.2 MJ/L	23.6 MJ/L

Propane Energy Content

$$\frac{32.2 - 23.6}{32.2} \times 100\% = 26.7\% \text{ less than gasoline}$$

Energy Consumption (MJ/100 km)

$$\text{Energy Cons. (MJ/100 km)} = \text{volumetric fuel cons. (L/100 km)} \times \text{liquid energy content (MJ/L)}$$

	AVERAGE VALUES	
	Urban	Highway
Gasoline (Previous)	= 14.9 x 32.2 = 480 MJ/100 km	= 11.5 x 32.2 = 371 MJ/100 km
Gasoline (Current)	= 16.6 x 32.2 = 535 MJ/100 km	= 12.6 x 32.2 = 406 MJ/100 km
Gasoline (W/Mixer)	= 15.7 x 32.2 = 506 MJ/100 km	= 12.1 x 32.2 = 390 MJ/100 km
DFA-Propane (Before)	= 22.6 x 23.6 = 533 MJ/100 km	= 18.5 x 23.6 = 437 MJ/100 km
DFA-Propane (After)	= 20.1 x 23.6 = 474 MJ/100 km	= 15.9 x 23.6 = 375 MJ/100 km
Previous Propane	= 21.3 x 23.6 = 503 MJ/100 km	= 16.5 x 23.6 = 389 MJ/100 km

DFA Average Relative Improvement vs. Gasoline

$$\frac{535 - 474}{535} \times 100\% = 11\% \text{ (Urban)}$$

$$\frac{406 - 375}{406} \times 100\% = 7\% \text{ (Highway)}$$

APPENDIX H/ CVS FUEL/ENERGY CONSUMPTION DATA

APPENDIX H/ CVS FUEL/ENERGY CONSUMPTION DATA

	VOLUMETRIC (L/100 km)		ENERGY (Average) (MJ/100 km)	
	Urban	Highway	Urban	Highway
Gas 1	16.77	12.72	535	406
Gas 2	16.82	12.88		
Gas 3	16.25	12.24		
Gas/Mixer 1	16.23	12.41	506	390
Gas/Mixer 2	15.45	11.95		
Gas/Mixer 3	15.57	11.92		
Propane-BEF1	22.27	18.65	533	437
Propane-BEF2	22.89	18.30		
Propane-AFT1	20.31	15.94	474	375
Propane-AFT2	19.87	15.92		
Prev. Conv.*	21.29	16.48	503	389
Old Gas**	14.89	11.52	480	371

Notes: *Average of 6 tests
 **Average of 3 tests

APPENDIX I/ CVS EXHAUST EMISSIONS DATA

APPENDIX I/ CVS EXHAUST EMISSIONS DATA

	SUBSTANCE (g/mi)		
	Hydrocarbons(HC)	Carbon Monoxide(CO)	Nitrous Oxides(NO _x)
Gas 1	0.937	9.890	1.060
Gas 2	1.120	11.860	0.924
Gas 3	0.878	12.030	1.090
Gas+Mixer1	0.838	4.270	1.070
Gas+Mixer2	0.692	3.450	1.100
Gas+Mixer3	0.699	3.250	1.070
Propane-BEF1	1.150	14.400*	0.383
Propane-BEF2	1.180	14.550	0.357
Propane-AFT1	1.080	4.020	1.220
Propane-AFT2	1.060	3.670	1.190

NOTE: * Estimate -- error in sample valve setting occurred.

APPENDIX J/ AIR/FUEL EQUIVALENCE RATIO DATA

APPENDIX J/ AIR/FUEL EQUIVALENCE RATIO DATA

	SPEED (km/h)						
	0(Idle)	32.2	48.3	64.4	80.5	88.5	96.6
Gas 1	0.667	0.978	1.045	0.980	0.976	0.962	0.956
Gas 2	0.672	0.949	1.050	0.956	0.986	0.955	0.968
Gas+Mixer1	0.796	1.018	1.085	1.002	1.008	0.999	0.980
Gas+Mixer2	0.806	1.040	1.010	1.006	1.026	1.002	0.990
Propane-BEF	1.554	1.192	1.048	0.948	0.908	0.858	0.848
Propane-AFT1	0.948	1.209	1.155	1.080	1.048	1.015	1.000
Propane-AFT2	0.890	1.163	1.106	1.048	1.029	0.999	0.990
Prev. Conv.*	1.04		1.06				1.11
Old Gas**	0.91		1.07				1.00

NOTES: * Average of 6 tests

** Average of 3 tests

APPENDIX K/ SPARK ADVANCE DATA

APPENDIX K/ SPARK ADVANCE DATA

Mechanical Spark Advance Data

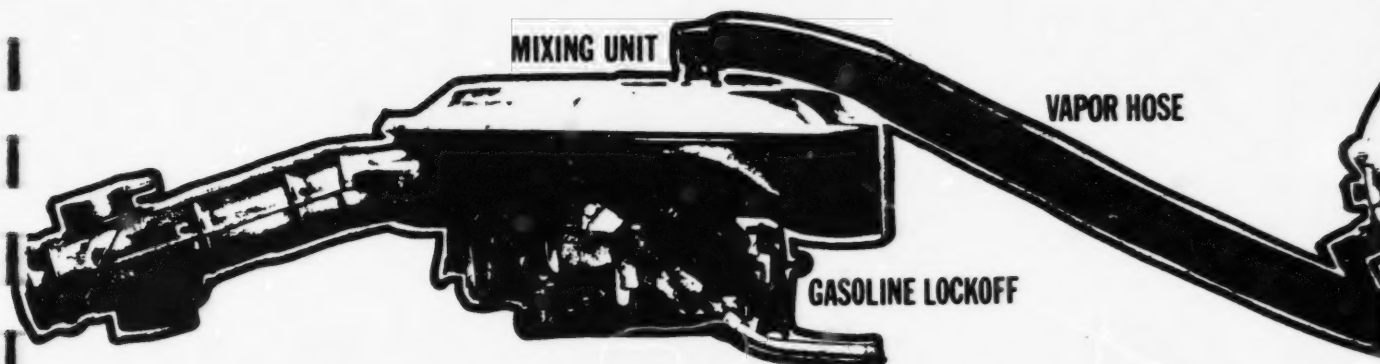
Dist.	DISTRIBUTOR DEGREES		FORD RECOMMENDATIONS	
	Gasoline/DFA-Propane	Prev. Conv.	Low Lim.	Upper Lim.
300	0	1	0	1
600	3	7	0	2
800	4	9	6	5.5
1000	4.9	9	6	8
1200	6	9	6	8.25
1400	7.5	9	6	8.6
1600	8	9	6	9

Vacuum Spark Advance Data

Dist. Vac.(in. Hg)	DISTRIBUTOR DEGREES		FORD RECOMMENDATIONS	
	Gasoline/DFA	Prev. Conv.	Low Lim.	Upper Lim.
0	0	0	0	0
2	0	0.5	0	0.5
4	1	3	0	1.5
6	3	6	0	2.8
8	4.5	6	3.5	7
10	5.5	6	6	9
12	6	6	8	10.5
14	6	6	8.75	11.25
16	6	6	8.6	11.25
18	6	6	8.55	11.25
20	6	6	8.4	11.25

APPENDIX L/ DFA MIXER SYSTEM

THE SYSTEM--GENERAL DESCRIPTION



PROPANE TANK

The propane fuel tank is constructed out of heavy gauge steel in accordance with NFPA code no. 58 (ASME and DOT specifications) to ensure a high degree of safety. The propane fuel tank is equipped with fittings for refilling, fuel outlet and safety relief valves. The propane tank is also equipped with a "float" type fuel gauge.

FUEL SUPPLY LINE

The fuel supply hose transfers fuel from the tank to the carburetion system. The hose is stainless steel reinforced and in accordance with the code--UL approved.

PROPANE LOCKOFF/FILTER

The propane lockoff is activated to open an electric solenoid. Clean fuel from the tank flows to the carburetion system through the lockoff/filter. When the power to the solenoid is switched off, the lockoff valve automatically closes. The propane lockoff/filter meets the NFPA code requirements--UL approved.

PROPANE CONVERTER/REGULATOR

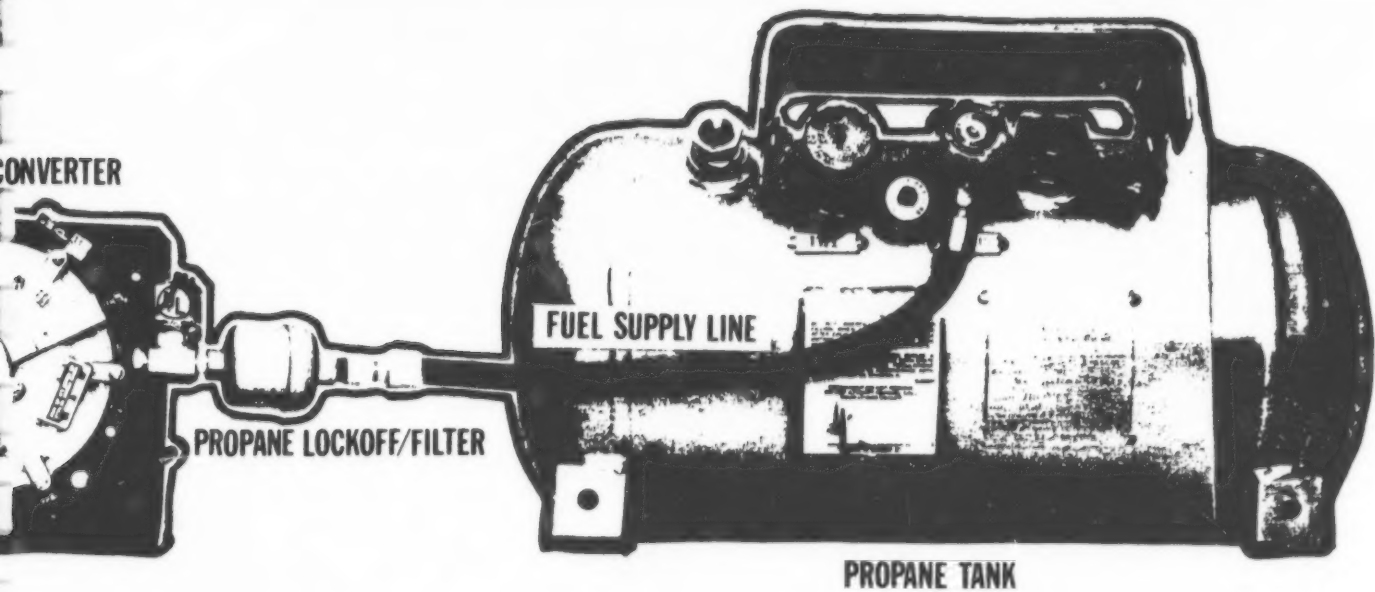
The function of the propane converter is to change the state of the propane from a pressurized liquid state to an ambient engine gaseous state. This is achieved through a compact converter whose sequence of functions are to expand the liquid propane and to heat and pressure regulate the resulting propane gas. Heat is supplied in the expansion phase by circulating the engine coolant through the converter. The converter is UL approved.

VAPOR HOSE

The vapor hose transfers the gaseous propane from the converter to the propane mixer.

PROPANE MIXER

The propane mixer is a simple device designed to accurately meter and mix propane and air for proper combustion. The fuel enters the mixer as a "dry" gas which mixes evenly with air for ideal fuel distribution. The DFA mixer complies with all requirements of the NFPA code.



GASOLINE LOCKOFF

The gasoline lockoff is used when switching from one fuel to the other. This is accomplished electrically via a fuel select switch inside the vehicle. The gasoline lockoff carries UL approval.

SUMMARY

Dual Fuels Associates, Corp. has assembled a carburetion kit that is well accepted and enthusiastically endorsed by many companies and individuals throughout the United States. Special care has been taken to make the system extremely easy to install and maintain.

We feel this breakthrough in carburetion technology will accelerate propane's acceptance as a competitive alternate fuel.

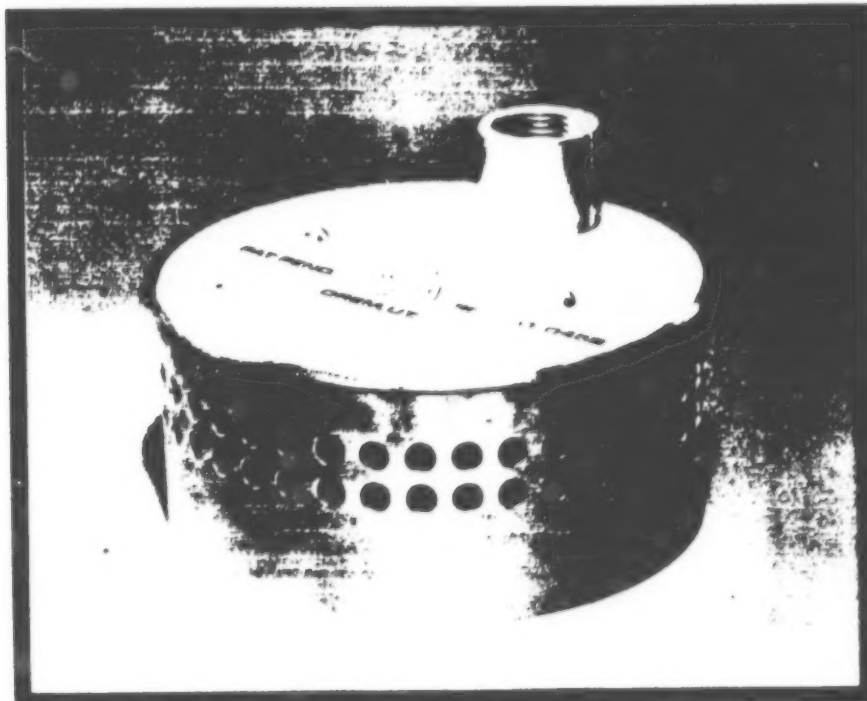
DFA CARBURETION KIT INCLUDES:

- Propane Lockoff / Filter
- Propane Converter / Regulator
- Vacuum Safety Switch
- Converter J-Mounting Bracket
- 1 Inch Dia. Neoprene Vapor Hose
- Propane Mixer w / Vapor Elbow
- Plastic Vacuum Tee
- Fuel Select Switch
- By-Pass (Prime) Switch
- 16 Gauge 3-Color Wire
- Wire Terminals
- Gasoline Lockoff w / Compression Fittings
- Hose Clamps
- Wire Ties
- Installation Instructions

SUGGESTED RETAIL COST:

THE DFA MIXER UNIQUE, INNOVATIVE, ADVANCED

The DFA System utilizes the existing gasoline carburetor throttle. Propane and air are drawn independently and simultaneously by ported vacuum¹ through a multiplicity of small orifices in the DFA Mixer. The directional flows of propane and air are designed to tangentially collide, providing an intimately mixed, near stoichiometric mixture² for peak combustion within the engine--a break through in carburetion technology.



CONTROL

The DFA System gives optimum performance and mileage; even under the most severe loads and conditions.

INSTALLATION

The DFA Carburetion System can be installed in less than two hours. (simplified installation instructions to aid the first-time installer)

PHYSICAL DESIGN

The DFA Mixing Unit was developed and designed to fit within the original air filter system; thus minimizing "head room" problems, and eliminating interference with the vehicle's emission control equipment.

ADJUSTMENTS & TUNE-UP

The DFA System has one simple adjustment for idle.

SAFETY

The increased air flow capacity on the DFA System eliminates the boden cable³, used in switching from one fuel to the other; thus simplifying the switchover operation, eliminating the lean-out hazard, and making the DFA System the safest dual fuel system in the world.

INTERCHANGEABILITY

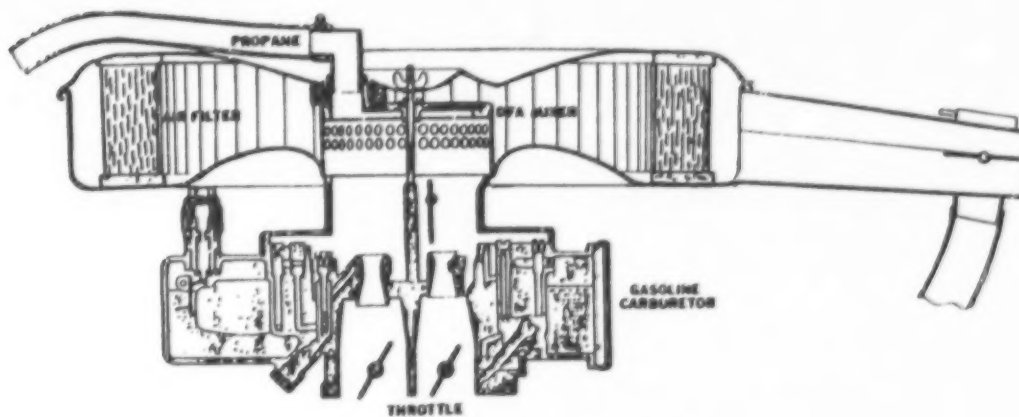
The standard DFA Mixing Unit fits the majority of the eight cylinder American Engines. Specific DFA Mixing Units are designed for vehicles outside this range.

MAINTENANCE

With the elimination of moving parts, maintenance of the DFA System is reduced to essentially fuel contamination problems.

1. Ported Vacuum--is the engine vacuum above the carburetor throttle body. Ported Vacuum is maximum when the throttle is at its wide open position, and is inversely proportional to engine manifold vacuum.
2. Stoichiometric Mixtue--is the exact proportion of air and propane to provide a chemically correct mixture for perfect combustion in the engine.
3. Boden Cable--is a manual linkage to physically open additional air ports to allow increased air flow to the engine. Conventional systems, restrictive on air, require additional air flow capacity when operating on gasoline.

CROSS SECTION OF STANDARD AIR CLEANER WITH DFA MIXER IN POSITION



DFA MIXER:

- (1) Totally mixes air and propane--giving power equivalent to gasoline.
- (2) Maintains fuel mixture stoichiometric from idle to full throttle.
- (3) No air restriction on gasoline.
- (4) Fits within existing (OEM) air cleaner.
- (5) Eliminates borden cable and safety hazard.
- (6) Retains all OEM equipment.
- (7) No moving parts--no maintenance.

